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**Permanent Plots for Measuring the Spread and Impact of Douglas-fir Dwarf
Mistletoe in the Southern Oregon Cascades, Pacific Northwest Region:**

Establishment and Five-Year Remeasurement Report



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Background

Douglas-fir dwarf mistletoe (*Arceuthobium douglasii*) is a parasitic, flowering plant found almost exclusively on Douglas-fir. It is widespread on Douglas-fir in both the Cascade and Siskiyou Mountain ranges of Southern Oregon. Studies have shown that heavy infections of Douglas-fir dwarf mistletoe reduce the growth of host trees and contribute to an increase in mortality rates. Heavy infections also often result in large brooms that are widely used for nesting and hiding cover by a large number of wildlife species. Because this parasite is widespread and has significant impacts on its host, stand development and ecosystem function, its effects should be included in the models that are used to predict stand development.

The Forest Vegetation Simulator Model (FVS) is the most widely used vegetation model in the Pacific Northwest Region. It incorporates the effects of dwarf mistletoes and other pathogens. Much of information used to develop relationships for the effects of Douglas-fir dwarf mistletoe in this model was derived from temporary plots and from data from other regions and other species of dwarf mistletoes. Data collected from permanent plots in Southwest Oregon is necessary to calibrate the model with local conditions, including growth and mortality of the host, the rate of spread and intensification of the parasite and patterns of stand development.

In 1990, a methodology for establishing permanent plots to measure the effects of dwarf mistletoe for simulation models was developed for Forest Pest Management (FPM) by Robert Mathiasen, then a Plant Pathologist for FPM in the Intermountain Region. The field manual describing this method (Work Plan, version 4.0, 1991) was used to install a series of permanent plots in Douglas-fir dwarf mistletoe-infected stands in the Southern Oregon Cascades. The data from these plots will be used to validate the Dwarf Mistletoe Impact Extension for the West Cascades and Interior California-Southern Cascades variants of FVS.

Plot Establishment and Initial Conditions

In 1992, eleven plots were installed on the Rogue River and Umpqua National Forests by Katy Marshall and a crew from Oregon State University (Figure 1). Plot locations were selected to include a variety of plant associations, and stand ages, structures and histories (Table 1). The plots are square, and vary in size from one third to one acre. Plot corners and centers are monumented with fiberglass pipe and reference trees. Reference trees are tagged, blazed and marked with white paint. Bearings and distances to the plot corners and centers are recorded on the tags and in Appendices D and E of the plot data.

At each plot the slope, aspect, site index and plant association were determined. Stand origin and the history of management and disturbance were estimated. All live trees greater than two inches in diameter at breast height (4.5 feet) were tagged and data were collected on: species, diameter breast height (dbh), Dwarf Mistletoe Rating (DMR, Hawksworth's six-class dwarf mistletoe rating system modified for Douglas-fir by Tinnin, 1998), crown class, and damage. Total height, height to the base of the live crown, breast height age, and ten-year radial growth were measured in a subsample of the live trees. Species and dbh were noted for all dead trees on the plots. Five of the plots were stem mapped for more accurate determination of mistletoe spread and intensification.

1,576 live trees were tagged in the eleven plots (Table 2). Of these, 732 (46 percent) were Douglas-fir. 327 (45 percent) of these Douglas-fir were dwarf mistletoe-infected. Initial infection levels ranged from 22 to 78 percent of the Douglas-fir in a plot. Other species of trees in the plots were white fir (36 percent), incense cedar (nine percent), western hemlock (three percent), Pacific yew (three percent), chinquapin (one percent), and bigleaf maple, Pacific madrone, sugar pine, ponderosa pine and Shasta red fir (each less than one percent).

Five-Year Remeasurement

During July and August, 1997 the plots were revisited by Katy Marshall (SWOFIDTC) and Greg Filip (Oregon State University). Condition (live or dead) and dbh were remeasured on all tagged trees. Damage agents were identified. Total heights and dwarf mistletoe ratings were remeasured on all live Douglas-fir.

Summary of Changes During the First Five Years

Infection: Overall, the proportion of live, infected Douglas-fir increased by six percent between 1992 and 1997 (Table 3). Among plots, the change ranged from a three percent decrease to a nineteen percent increase. Factors that may have contributed to a decrease in the level of infection in some plots include: greater mortality among infected than uninfected trees, or trees identified as infected when the plots were established but uninfected when they were remeasured. There are seventeen trees in this latter category (the brooms may have died or broken off, or errors may have been made in the ratings).

The proportion of infected Douglas-fir increased in all size classes, except small trees (Table 4). The increase was greatest in the sapling size class. The proportion of infected Douglas-fir also increased in all crown classes (Table 5). The increase was greatest in the suppressed class, and least in the predominant class.

Mortality: Between 1992 and 1997, 119 (8 percent) of the tagged trees died (Table 3). Fifty-two (44 percent) of these trees were Douglas-fir. Thirty-one (60 percent) of the Douglas-fir trees that died were mistletoe-infected.

Mortality of Douglas-fir occurred in nine of the plots. In seven of these plots the majority of the dead Douglas-fir were mistletoe-infected (Table 6). In all of the plots with dead, infected Douglas-fir, the average Dwarf Mistletoe Index (DMI, the average dwarf mistletoe rating of infected trees) was 3.0 and greater. This indicates that on average, at least half the crowns of the dead infected trees were involved in mistletoe brooms.

In all size classes where mortality occurred, except the pole size class, more infected than uninfected Douglas-fir died between measurements (Table 4). Infected saplings had the highest level of mortality. There was no mortality in the medium or large tree size classes. Similarly, in all crown classes where mortality occurred, more infected than uninfected Douglas-fir died (Table 5). Infected, suppressed Douglas-fir had the highest level of mortality. There was no mortality among the dominant trees.

The average DMI of saplings and suppressed Douglas-fir that died was lower than the average DMI of live trees in those classes. The average DMI of poles, small Douglas-fir and very large Douglas-fir that died between measurements was higher than the average DMI of live Douglas-fir in those size classes (Table 4). The average DMI of Douglas-fir in the intermediate, codominant and predominant crown classes was also higher among trees that died between measurements than the average DMI of live Douglas-fir in those crown classes (Table 5).

The DMIs show that on average, about half the crown of infected saplings and suppressed Douglas-fir that died were involved in brooms, compared to two-thirds or more of the crown of the infected, dead trees in larger size and crown classes.

Fourteen percent of the uninfected, dead Douglas-fir and 35 percent of the infected, dead Douglas-fir were killed by windthrow, snow or wind breakage. One infected, live tree was under attack by Douglas-fir beetles.

Growth: Over the five-year period, overall average diameter growth of infected Douglas-fir was 0.52 inches, compared to 0.75 inches for uninfected Douglas-fir (Table 7). In plots 1, 4, 5, 6, 7, 8 and 13, 14, 15 and 16, average diameter growth for the five-year period was greater among uninfected than infected Douglas-fir. However, in plots 2, 3 and 9 the average diameter growth was greater among the infected Douglas-fir. In plots 2 and 9 the difference between average growth of infected and uninfected trees was very small (0.03 and 0.04 inches, respectively). In plot 3 the difference between the two groups was much larger (0.50 inches) and may have been related to the stand structure. The large, dominant Douglas-fir in this plot, many of which are infected, may still have higher growth rates than the understory trees, most of which are free of mistletoe, but are very suppressed. Plot 7 has much higher growth rates among both infected and uninfected trees than any of the other plots. The stand this plot is in was commercially thinned prior to plot establishment.

Analysis of height growth will be done after the ten-year remeasurement because of the large number of trees that shrank in height between plot establishment and the five-year remeasurement. Most of the shrinkage was within the limits of differences that would be expected from repeated measurements of tree height by different people using clinometers (≤ 5 feet for trees 100 feet tall), and suggests that these trees did not grow significantly in height during the five year period. However, some trees shrank by larger amounts. These trees have been identified and should be remeasured very carefully to determine which of the previous measurements was correct. This problem occurred most frequently in Plot 14, which has very tall Douglas-fir that were extremely difficult to measure accurately due to the flat terrain and dense understory.

Dwarf mistletoe ratings: In plots 1, 2, 3, 4, 5 and 13, the average plot DMR increased by 0.1 to 0.5 rating classes during the five-year period (Table 8). In plot 9, the DMR decreased by 0.1 class and in plot 7 it showed no change. In plots 1, 2, 3, 4, 5, 7, 9 and 13, DMI also increased or decreased by 0.5 rating classes or less. This rate of change is similar to that found in other studies of dwarf mistletoe spread and intensification (Ellen Goheen, Plant Pathologist, SWOFIDTC, personal communication). In plots 8, 14 and 16, the average plot DMR and DMI decreased by 0.7 to 1.9 rating classes. There are several possible explanations for this level of decrease. The infected trees could have grown more in height than the mistletoe advanced in the

crowns, infected branches could have died or been broken off, heavily infected trees could have died, or there could have been errors in rating during plot establishment or remeasurement.

413 (61%) of the 680 Douglas-fir alive in 1997 had no change in DMR from 1992. 163 (24%) changed by one rating class and 57 (8%) changed by two rating classes. 46 trees (7%) changed by three to six rating classes (Table 9). It seems improbable that the level of infection would change by more than two rating classes in a five-year period. It is possible that these trees were rated incorrectly at either the first or second measurement. There appear to be more of these trees among those that were initially rated in the higher DMR classes. Most of them are in plots 4, 8 and 14.

Recommendations for the Ten-Year Remeasurement

The ten year remeasurement of the plots will be due in 2002. At this time, all the variables that were measured at plot establishment will be remeasured. Ingrowth will be tagged and measured. The plant associations will be redetermined to meet the new classification standards (Atzet et al, 1996).

I recommend dropping Plot 14, from future measurements. The same conditions in this plot that made tree heights so difficult to measure accurately also made the Dwarf Mistletoe Ratings difficult.

In the other plots, trees with DMRs that seem unrealistic have been identified and should be re-rated very carefully to determine which of the previous ratings were in error (the majority of these trees are in plots 4, 8 and 16). Otherwise, it may be advisable to drop trees with DMRs that cannot be reconciled. If possible, it would be best to remeasure all trees with DMR or height discrepancies in 1999 rather than waiting until 2002.

I also suggest that raters be familiar with the dwarf mistletoe ratings from the previous measurements to make sure that their rating and the previous ratings make sense together. This would prevent discrepancies in rating due to differences between people (or between one person's perception at five year intervals).

Summary

The majority of Douglas-fir trees showed no change in the level of dwarf mistletoe after five years. However, some trees changed by one, or even two rating classes during that period. The average plot DMR and DMI also changed after five years, but in the majority of plots the changes were less than a full rating class.

Five years after the plots were established, impacts associated with Douglas-fir dwarf mistletoe infection are apparent. Infected Douglas-fir had less diameter growth and higher levels of mortality than uninfected Douglas-fir. The highest levels of mortality were among infected saplings and suppressed trees. On the other hand, there was no mortality among medium and large trees or dominant trees. These trends confirm the validity of assumptions about Douglas-fir dwarf mistletoe and mortality in the FVS model. They also support observations that

Douglas-fir that become heavily infected while they are small are unlikely to produce large trees in the future.

References

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Table 1. Stand Summary by Plot

Plot	Forest	District	Stem Mapped	Plot Size (acres)	Stand Structure	Stand History	Site Index			Plant Association
							DF	WF	WH	
1	Rogue	Ashland	N	1/2	U	uncut	82	67		ABCO-CADE3/BENE
2	Rogue	Ashland	Y	1	E	salvaged	92	86		ABCO-PSME/BEPI
3	Rogue	Ashland	N	1/3	E	uncut	82	87		ABCO-PSME/BEPI
4	Rogue	Ashland	N	1/2	U	uncut	84			ABCO-PSME/BEPI
5	Rogue	Butte Falls	N	1/2	E	uncut	93	88		ABCO-ABMAS/CHUM
7	Rogue	Butte Falls	Y	1	E	thinned	115			ABCO/BENE/ANDE
8	Rogue	Butte Falls	Y	1/2	U	uncut	90		66	TSHE/BENE/LIBOL
9	Rogue	Prospect	N	1/3	E	thinned	103	82		ABCO-CADE3/BENE
13	Rogue	Prospect	Y	1	E	partial cut	107	96		ABCO/RUNI/ACTR
14	Umpqua	Tiller	N	1/2	E	uncut			120	TSHE/RHMA/LIBOL
16	Umpqua	Tiller	Y	1/2	E	thinned	84			ABCO-CADE3/BENE

Stand structure: U=uneven-aged (at least 3 age classes), E=even-aged (one or two age classes)

Site Indices: DF from Schumacher (1930)
WF from Schumacher (1926)
WH from Barnes (1962)

Plant Associations: Atzet, T. and L. McCrimmon (1990)

Table 2. Tree Summary by Plot, 1992

Plot	Number of tagged trees	Number of live trees	Number of live DF	Number of live DF infected	Percent live DF infected
1	201	201	44	24	55
2	200	200	108	42	39
3	131	131	40	22	55
4	199	199	114	68	60
5	111	109	55	18	33
7	101	101	78	17	22
8	88	88	15	9	60
9	140	140	100	22	22
13	201	201	101	46	46
14	66	66	22	16	73
16	141	140	55	43	78
Totals	1579	1576	732	327	45

Table 3. Tree Summary by Plot, 1997

Plot		Number of live trees	Number of live DF	Number of live DF infected	Percent live DF infected	change from 1992 (%)
1		181	38	28	74	+19
2		190	98	38	39	0
3		107	38	28	74	+19
4		182	104	78	75	+15
5		95	50	23	46	+13
7		101	78	18	23	+1
8		84	15	11	73	+13
9		127	92	19	21	-1
13		192	95	52	55	+9
14		64	20	15	75	-2
16		134	52	39	75	-3
Totals		1457	680	349	51	+6

Table 4. Infection and Mortality of Douglas-fir by Size Class

Size Class	dbh (inches)	% infected in 1992 (live)	% infected in 1997 (live)	DMI in 1992	DMI in 1997	% infected that died between 1992 and 1997	DMI of dead	% uninfected that died between 1992 and 1997
saplings	< 6.0"	39	62	2.8	3.3	28	2.9	15
poles	6.0-11.9"	46	55	3.5	3.5	11	4.8	11
small trees	12.0-15.9"	50	49	3.3	2.8	14	4.9	1
medium trees	16.0-20.9"	40	46	3.2	2.5	0	-	0
large trees	21.0-35.9"	43	46	3.0	2.2	0	-	0
very large trees	>36.0"	67	73	4.7	2.9	10	6.0	0

Table 5. Infection and Mortality of Douglas-fir by Crown Class

Crown class	% infected in 1992 (live)	% infected in 1997 (live)	DMI in 1992	DMI in 1997	% infected that died between 1992 and 1997	DMI of dead	% uninfected that died between 1992 and 1997
suppressed	35	57	2.6	3.1	28	2.7	17
intermediate	51	58	3.8	3.7	13	4.6	9
codominant	43	45	2.9	2.5	5	5.2	2
dominant	37	46	3.2	2.2	0	-	0
predominant	75	76	4.3	2.8	7	6.0	0

Table 6. Five-Year Douglas-fir Mortality by Plot

Plot	Number of dead DF	% of total number DF	Number of dead DF infected	% of dead DF infected	average DMR of dead DF	average DMI of dead DF
1	6	14	4	67	3.3	5.0
2	10	9	6	60	1.9	3.2
3	2	5	2	100	3.0	3.0
4	10	9	8	80	4.3	5.4
5	5	9	0	0	0.0	-
7	0	0	0	0	-	-
8	0	0	0	0	-	-
9	8	8	1	13	0.8	6.0
13	6	6	5	83	2.5	3.0
14	2	9	2	100	6.0	6.0
16	3	5	3	100	5.3	5.3
Totals	52	7	31	60	2.6	4.4

Table 7. Average Diameter Growth of Infected and Uninfected Douglas-fir by Plot

Plot	Diameter growth (inches)	
	infected DF	uninfected DF
1	0.38	0.47
2	0.60	0.57
3	0.67	0.17
4	0.28	0.50
5	0.42	0.68
7	1.35	1.52
8	0.69	0.73
9	0.49	0.45
13	0.69	0.91
14	0.24	0.52
16	0.45	0.67
Overall average	0.52	0.75

Table 8. Average Plot DMR and DMI (live Douglas-fir)

Plot	DMR 1992	DMR 1997	Change in DMR	DMI 1992	DMI 1997	Change in DMI
1	2.0	2.5	+0.5	2.9	3.4	+0.5
2	1.1	1.2	+0.1	2.9	3.1	+0.2
3	1.4	1.9	+0.5	2.5	2.6	+0.1
4	2.2	2.5	+0.3	3.6	3.3	-0.3
5	0.7	0.8	+0.1	2.2	1.8	-0.4
7	0.4	0.4	0.0	2.0	1.9	-0.1
8	2.9	2.2	-0.7	4.9	3.0	-1.9
9	0.6	0.5	-0.1	2.5	2.6	+0.1
13	1.5	1.7	+0.2	3.4	3.0	-0.4
14	3.6	2.3	-1.3	4.7	3.1	-1.6
16	3.2	2.1	-1.1	4.0	2.8	-1.2

Table 9. Percent of DF changing DMR by 0, 1, 2, 3, 4, 5 or 6 classes between 1992 and 1997

	Number of DMR classes changed												
	0	+1	-1	+2	-2	+3	-3	+4	-4	+5	-5	+6	-6
plot 1													
% of 38 DF	47	26	8	11	0	5	0	3	0	0	0	0	0
plot 2													
% of 98 DF	77	6	7	2	3	1	2	0	2	0	0	0	0
plot 3													
% of 38 DF	42	32	8	5	3	8	0	3	0	0	0	0	0
plot 4*													
% of 104 DF	37	24	12	8	7	8	1	2	1	0	0	2	0
plot 5													
% of 50 DF	66	16	8	2	6	2	0	0	0	0	0	0	0
plot 7													
% of 78 DF	89	1	8	1	0	0	0	1	0	0	0	0	0
plot 8*													
% of 15 DF	47	13	7	0	20	0	13	0	0	0	0	0	0
plot 9													
% of 92 DF	79	4	8	2	3	1	0	0	0	1	0	0	1
plot 13													
% of 95 DF	62	18	12	3	1	1	1	2	0	0	0	0	0
plot 14*													
% of 20 DF	35	10	30	0	5	0	10	0	10	0	0	0	0
plot 16													
% of 52 DF	35	6	25	0	23	0	4	0	4	0	2	0	0

* plots in which more than 10% of the DF changed DMR by three or more rating classes